

IN THE CLAIMS

Please take action regarding the claims so that the status is as follows:

1-23 (canceled).

24 (New) A scanning probe microscope apparatus for increased-quality-factor intermittent contact imaging of a sample surface comprising:

- A. a device including 1) a base, 2) a member which is displaceable relative to the base, 3) a tip mounted on the member to intermittently contact the sample surface to be imaged, and 4) a characteristic of an inherent/open-loop dynamic compliance function which includes frequency-dependent real and imaginary parts, the inherent/open-loop dynamic compliance function defining an inherent/open-loop quality factor, both the inherent/open-loop dynamic compliance function and the inherent/open-loop quality factor being specific to a reference position at which the tip is physically remote from the sample surface;
- B. means for actuating the member;
- C. means for measuring displacements of the member relative to the base and generating a displacement signal indicative thereof;
- D. an oscillator generating a driving signal which includes characteristics of 1) a driving frequency and 2) a driving amplitude, the driving signal causing oscillations in the means for actuating which in turn causes the member to oscillate which in turn causes the displacement signal to oscillate;
- E. a feedback controller receiving 1) the displacement signal and 2) the driving signal and applying an oscillatory

actuation signal to the means for actuating, the oscillatory actuation signal being mathematically dependent on 1) the displacement signal, 2) the driving signal, and 3) a gain function of the feedback controller which generally includes frequency-dependent real and imaginary parts, the gain function and the inherent/open-loop dynamic compliance function together establishing an operative/closed-loop resonance condition specific to the reference position, the operative/closed-loop resonance condition including characteristics of 1) an operative/closed-loop resonance frequency, 2) an operative/closed-loop resonance amplitude, and 3) an operative/closed-loop quality factor, the gain function causing a positive phase margin of stability but being such that the operative/closed-loop quality factor is higher than the inherent/open-loop quality factor, the driving frequency being equal to or near the operative/closed-loop resonance frequency, the operative/closed-loop resonance amplitude being sufficiently large to prevent the tip from becoming stuck to the sample surface but being sufficiently small to prevent the sample surface from becoming excessively damaged while the tip intermittently contacts the sample surface; and

F. a scanner for altering a separation distance between the sample surface and the device in a direction predominantly perpendicular to the sample surface and for imparting relative motions between the sample surface and the device in a plane predominantly parallel to the sample surface.

25 (New) A scanning probe microscope apparatus in accordance with claim 24 further comprising:

A. an amplitude detector measuring a displacement amplitude of the displacement signal and generating a displacement

amplitude signal indicative thereof, the displacement amplitude being smaller while the tip intermittently contacts the sample surface in comparison to when the device is at the reference position;

- B. a phase detector measuring a phase of the displacement signal with respect to a reference signal and generating a phase signal indicative thereof;
- C. means for controlling the scanner including means for 1) receiving the displacement amplitude signal, 2) setting a demanded displacement amplitude, 3) controlling the separation distance to bring the tip into intermittent contact with the sample surface and to maintain the displacement amplitude in general agreement with the demanded displacement amplitude while the tip intermittently contacts the sample, and 4) driving the relative motions to raster scan the sample surface; and
- D. an imager operatively coupled to 1) the means for controlling the scanner, 2) the amplitude detector, and 3) the phase detector, the imager forming spatially-correlated images derived from 1) the separation distance, 2) a discrepancy between the displacement amplitude and the demanded displacement amplitude, and 3) the phase.

26 (New) A scanning probe microscope in accordance with claim 24 wherein the displacements are displacements of translation.

27 (New) A scanning probe microscope in accordance with claim 24 wherein the displacements are displacements of rotation.

28 (New) A scanning probe microscope in accordance with claim 24 wherein the displacements are displacements of bending.

29 (New) A scanning probe microscope in accordance with claim 24 wherein the displacements are displacements of torsion.

30 (New) A scanning probe microscope apparatus in accordance with claim 24 wherein the inherent/open-loop quality factor is indicative of over-damped oscillations and wherein the inherent/closed-loop quality factor is indicative of under-damped oscillations.

31 (New) A scanning probe microscope apparatus in accordance with claim 24 wherein the inherent/closed-loop quality factor is at least one order of magnitude higher than the inherent/open-loop quality factor.

32 (New) A scanning probe microscope apparatus in accordance with claim 24 wherein the tip is in a liquid when the device is at the reference position and wherein the tip is in the liquid while the tip intermittently contacts the sample surface.

33 (New) A scanning probe microscope apparatus in accordance with claim 32 wherein the liquid includes a characteristic of an absolute viscosity as high as 1490 centipoise (cP).

34 (New) A scanning probe microscope apparatus in accordance with claim 24 wherein the device further includes two stationary electrodes facing the member without contacting the member, the member being electrically conducting to define a pair of variable capacitors.

35 (New) A scanning probe microscope apparatus in accordance with claim 34 wherein the means for actuating includes electrostatic/capacitive forces.

36 (New) A scanning probe microscope apparatus in accordance with claim 34 wherein the means for measuring includes 1) the pair of variable capacitors, 2) a pair of modulation signals nominally 180 degrees out of phase with respect to each other and sufficiently high in frequency to not displace the member relative to the base, 3) a preamplifier, 4) a demodulator, and 5) a low-pass filter.

37 (New) A scanning probe microscope apparatus in accordance with claim 24 wherein the oscillatory actuation signal includes a dc component derived from feedback which tends to maintain a constant dc level of the displacements for all reasonable separation distances.

38 (New) A scanning probe microscope apparatus in accordance with claim 24 wherein the tip is of a form appropriate for nanoindentation.

39 (New) An interfacial force microscope for increased-quality-factor intermittent contact imaging of a sample surface comprising:

- A. a differential-capacitance displacement sensor including 1) a base, 2) a member which is rotationally displaceable relative to the base, 3) a tip mounted on the member to intermittently contact the sample surface to be imaged, and 4) a characteristic of an inherent/open-loop dynamic compliance function which includes frequency-dependent real and imaginary parts, the inherent/open-loop dynamic compliance function defining an inherent/open-loop quality factor, both the inherent/open-loop dynamic compliance function and the inherent/open-loop quality factor being

- specific to a reference position at which the tip is physically remote from the sample surface;
- B. means for actuating the member via electrostatic/capacitive forces;
 - C. means for measuring rotational displacements of the member relative to the base and generating a displacement signal indicative thereof;
 - D. an oscillator generating a driving signal which includes characteristics of 1) a driving frequency and 2) a driving amplitude, the driving signal causing oscillations in the means for actuating which in turn causes the member to oscillate rotationally which in turn causes the displacement signal to oscillate;
 - E. a force-feedback controller including 1) a summing junction and 2) a control block, the summing junction receiving 1) the displacement signal and 2) the driving signal and generating an error signal indicative of a discrepancy between the displacement signal and the driving signal, the control block receiving the error signal and applying an oscillatory actuation signal to the means for actuating, the oscillatory actuation signal being mathematically dependent on 1) the error signal and 2) a gain function of the force-feedback controller which generally includes frequency-dependent real and imaginary parts, the gain function and the inherent/open-loop dynamic compliance function together establishing an operative/closed-loop resonance condition specific to the reference position, the operative/closed-loop resonance condition including characteristics of 1) an operative/closed-loop resonance frequency, 2) an operative/closed-loop resonance amplitude, and 3) an operative/closed-loop quality factor, the gain function causing a positive phase margin of stability but being such

that the operative/closed-loop quality factor is higher than the inherent/open-loop quality factor, the driving frequency being equal to or near the operative/closed-loop resonance frequency, the operative/closed-loop resonance amplitude being sufficiently large to prevent the tip from becoming stuck to the sample surface but being sufficiently small to prevent the sample surface from becoming excessively damaged while the tip intermittently contacts the sample surface; and

- F. a scanner for altering a separation distance between the sample surface and the differential-capacitance displacement sensor in a direction predominantly perpendicular to the sample surface and for imparting relative motions between the sample surface and the differential-capacitance displacement sensor in a plane predominantly parallel to the sample surface.

40 (New) An interfacial force microscope in accordance with claim 39 further comprising:

- A. an amplitude detector measuring a displacement amplitude of the displacement signal and generating a displacement amplitude signal indicative thereof, the displacement amplitude being smaller while the tip intermittently contacts the sample surface in comparison to when the device is at the reference position;
- B. a phase detector measuring a phase of the displacement signal with respect to a reference signal and generating a phase signal indicative thereof;
- C. means for controlling the scanner including means for 1) receiving the displacement amplitude signal, 2) setting a demanded displacement amplitude, 3) controlling the separation distance to bring the tip into intermittent

contact with the sample surface and to maintain the displacement amplitude in general agreement with the demanded displacement amplitude while the tip intermittently contacts the sample, and 4) driving the relative motions to raster scan the sample surface; and

D. an imager operatively coupled to 1) the means for controlling the scanner, 2) the amplitude detector, and 3) the phase detector, the imager forming spatially-correlated images derived from 1) the separation distance, 2) a discrepancy between the displacement amplitude and the demanded displacement amplitude, and 3) the phase.

41 (New) An interfacial force microscope in accordance with claim 39 wherein the inherent/open-loop quality factor is indicative of over-damped oscillations and wherein the inherent/closed-loop quality factor is indicative of under-damped oscillations.

42 (New) An interfacial force microscope in accordance with claim 39 wherein the inherent/closed-loop quality factor is at least one order of magnitude higher than the inherent/open-loop quality factor.

43 (New) An interfacial force microscope in accordance with claim 39 wherein the tip is in a liquid when the device is at the reference position and wherein the tip is in the liquid while the tip intermittently contacts the sample surface.

44 (New) An interfacial force microscope in accordance with claim 43 wherein the liquid includes a characteristic of an absolute viscosity as high as 1490 centipoise (cP).

45 (New) An interfacial force microscope in accordance with claim

39 wherein the differential-capacitance displacement sensor further includes 1) two oppositely extending torsion bars supporting the member and 2) two stationary electrodes located beneath the member without contacting the member, the member being electrically conducting to define a pair of variable capacitors.

46 (New) An interfacial force microscope in accordance with claim 45 wherein the means for measuring includes 1) the variable capacitors, 2) a pair of modulation signals nominally 180 degrees out of phase with respect to each other and sufficiently high in frequency to not displace the member relative to the base, 3) a preamplifier, 4) a demodulator, and 5) a low-pass filter.

47 (New) An interfacial force microscope in accordance with claim 39 wherein the control block includes proportional, integral, and derivative gains.

48 (New) An interfacial force microscope in accordance with claim 39 wherein the oscillatory actuation signal includes a dc component derived from feedback which tends to maintain a constant dc level of the displacements for all reasonable separation distances.

49 (New) An interfacial force microscope in accordance with claim 39 wherein the tip is of a form appropriate for nanoindentation.

50 (New) A method of increased-quality-factor intermittent contact imaging of a sample surface for a scanning probe microscope apparatus comprised of 1) a device including i) a base, ii) a member which is displaceable relative to the base, iii) a tip mounted on the member to intermittently contact the

sample surface, iv) a characteristic of an inherent/open-loop natural frequency, and v) a characteristic of an inherent/open-loop quality factor, both the inherent/open-loop natural frequency and the inherent/open-loop quality factor being specific to a reference position at which the tip is remote from the sample surface, 2) means for actuating the member, 3) means for measuring displacements of the member relative to the base and generating a displacement signal indicative thereof, 4) an oscillator generating a driving signal which includes characteristics of i) a driving frequency and ii) a driving amplitude, the driving signal causing oscillations in the means for actuating which in turn causes the member to oscillate which in turn causes the displacement signal to oscillate, and 5) a feedback controller receiving i) the displacement signal and ii) the driving signal and applying an oscillatory actuation signal to the means for actuating, the oscillatory actuation signal being mathematically dependent on i) the displacement signal, ii) the driving signal, and iii) a gain function of the feedback controller which generally includes frequency-dependent real and imaginary parts, the method comprising the steps of:

A. setting the driving amplitude above zero and placing the device at the reference position;

B. while the device is at the reference position:

- a. measuring a displacement amplitude of the displacement signal for a plurality of driving frequencies which include the natural frequency and generating an operative/closed-loop spectrum of displacement amplitudes versus driving frequencies, and
- b. adjusting the gain function in a manner which causes a positive phase margin of stability but produces an operative/closed-loop resonance peak in the operative/closed-loop spectrum, the operative/closed-

loop resonance peak including characteristics of 1) an operative/closed-loop resonance frequency, 2) an operative/closed-loop resonance amplitude, and 3) an operative/closed-loop quality factor higher than the inherent/open-loop quality factor;

C. after adjusting the gain function:

- a. setting the driving frequency equal to or near the operative/closed-loop resonance frequency, and
- b. setting the driving amplitude such that the operative/closed-loop resonance amplitude is sufficiently large to prevent the tip from becoming stuck to the sample surface but sufficiently small to prevent the sample surface from becoming excessively damaged while the tip intermittently contacts the sample surface; then

D. placing the device at an imaging position at which the tip intermittently contacts the sample surface; and

E. while the device is at the imaging position:

- a. controlling a separation distance between the sample surface and the device in a manner which maintains the displacement amplitude in general agreement with a demanded displacement amplitude, the separation distance being in a direction predominantly perpendicular to the sample surface, the demanded displacement amplitude being lower than the operative/closed-loop resonance amplitude ultimately established at the reference position, and
- b. imparting relative motions between the sample surface and the device in a plane predominantly parallel to the sample surface to raster scan the sample surface.

51 (New) A method in accordance with claim 50 further comprising

the steps of:

- A. measuring a phase of the displacement signal with respect to a reference signal while imaging the sample surface; and
- B. forming spatially-correlated images derived from 1) the separation distance, 2) a discrepancy between the displacement amplitude and the demanded displacement amplitude, and 3) the phase.

52 (New) A method in accordance with claim 50 wherein the step of adjusting the gain function causes the operative/closed-loop quality factor to be at least one order of magnitude higher than the inherent/open-loop quality factor.

53 (New) A method in accordance with claim 50 wherein the step of placing the device at the reference position places the tip in a liquid, wherein the step of adjusting the gain function tends to negate an effect of damping imparted by the liquid, and wherein the step of placing the device at the imaging position places the tip in the liquid.